VARIABILITY IN THE SPREADING PATHWAYS OF THE RED SEA AND PERSIAN GULF OUTFLOWS

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LONG-TERM GOALS

The long-range objective of this study is to understand the mechanisms that affect the spreading and mixing of marginal sea outflows. On-going analysis of AXBT observations in the outflow regions of the Red Sea and Persian Gulf has revealed significant variability in the strength and spreading pathways of these outflows. This is in sharp contrast to the Mediterranean Water outflow, which consistently follows more or less the same path for several hundred kilometers along the northern rim of the Gulf of Cadiz (see, *e.g.*, Baringer and Price, 1997). The most likely causes of the variability in the pathways of the Red Sea and Persian Gulf Water are seasonal variations in outflow transport and the mesoscale eddy variability in the outflow regions, which may be quite strong compared to the outflow velocities.

OBJECTIVES

1) Describe the synoptic mesoscale circulation in the Red Sea and Persian Gulf outflow regions (Gulf of Aden and Gulf of Oman, respectively) using seasonally repeated AXBT surveys conducted by he US Naval Oceanographic Office (NAVOCEANO).

2) Assess the role of mesoscale circulation features in the spreading of Red Sea and Persian Gulf Water.

APPROACH

1) Collect all available historical temperature-salinity data from NAVOCEANO's MOODS data archive with the assistance of Mr. Bob Rushton, manager of the data archive.

2) Use the historical temperature-salinity data with the AXBT data to map the dynamic height in the Gulf of Aden and Gulf of Oman for each of the AXBT surveys. Data organization will be handled by Ms. Carol Alessi (WHOI).

3) Compare dynamic height fields with temperature fields at the equilibrium depth of the outflows to look for impact of mesoscale eddies on outflow pathways. Ms. Alessi and Ms. Heather Hunt will assist with data analysis and interpretation. Guidance from Mr. Jeff Kerling of the Survey Plane Division at NAVOCEANO, who was responsible for the

AXBT observations, will also be sought.

WORK COMPLETED

A manuscript entitled "The Red Sea and Persian Gulf Outflows" was submitted to *The Journal of Geophysical Research* in June 1997 (Bower and Price, 1997). Results from this study were also presented in a poster at the AGU Fall Meeting in December 1996, and in two seminars in July 1997 (WHOI and the University of Washington). The hydrographic data from MOODS has been obtained on magnetic tape and we are proceeding with quality control of the data set.

RESULTS

An exploratory study has been carried out to investigate the structure and variability of the Red Sea and Persian Gulf outflows in the regions immediately downstream of their respective sources. Unlike the high-latitude marginal sea outflows in the Atlantic, the Red Sea and Persian Gulf outflows flow over relatively shallow sills (< 150 m) into an oceanic environment with a strong pycnocline, resulting in entrainment of near-surface water and comparatively large changes in temperature, salinity and density. Repeated, synoptic Air-Deployed Expendable Bathythermograph (AXBT) surveys in the outflow regions (Gulf of Aden and Gulf of Oman) have shown that newly-injected outflow water is often found in continuous veins or patches along the continental slopes to the right of the straits (facing seaward), indicating that advection in narrow boundary currents is likely an important process in the eastward transport of the heat and salt content of these outflows. Spreading of outflow water through the stirring action of mesoscale circulation features and formation of coherent eddies was also observed. The Red Sea outflow is particularly characterized by a multi-layer structure, possibly due to flow through different channels in Bab-el-Mandeb Strait. Both outflows exhibit temporal variability in temperature and equilibrium depth: in the case of the Red Sea outflow, this can be qualitatively explained in terms of seasonal variability of the entrained oceanic water from the upper 200 m. Numerical simulations of these outflows predict a 3-5-fold increase in volume transport due to turbulent entrainment. This result emphasizes the importance of the oceanic properties in setting the product water properties of the outflows.

IMPACT/APPLICATIONS

The Red Sea and Persian Gulf outflows are unique among better-known marginal sea outflows in that they exhibit seasonal variability in outflow transport, and flow into a well-stratified oceanic environment at relatively low latitude. The study of these outflows is leading to a broader understanding of the spreading and mixing of marginal sea outflows and their impact on the oceanic environment.

TRANSITIONS

Results from this study are being shared with NAVOCEANO through Mr. Jeff Kerling of the Survey Plane Division.

REFERENCES

Baringer, M. O'Neil, and J. F. Price, 1997. Mixing and spreading of the Mediterranean outflow. *Journal of Physical Oceanography, 27,* 1654-1677.

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